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A Ballooned Wireless Mesh Network for Disaster Response

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Background

- East Japan Great Earthquake in March 11th in 2011 caused sever damage over the wide area of Northern Japan.
- 5,841 persons died and 3,490 are missing due to the great tsunami
- The tsunami destoryed power supply, information systems and communication lines on the ground
- It is strongly required to quickly reconstruct emergency network
  - to recover from disorder
  - to provide urgent hotspot at evacuated places
  - to connect to Internet and regional intranet
  - to provide information services for evaluated residents

Background

Advantages of WLAN as disaster information network are

- Robust in case of disaster and less failure
- No cable disconnection,
- Quickly reconstruct network and establish the emergency information system just after occurrence of disaster
- Mobile communication environment using vehicles with WLAN to organize adhoc network

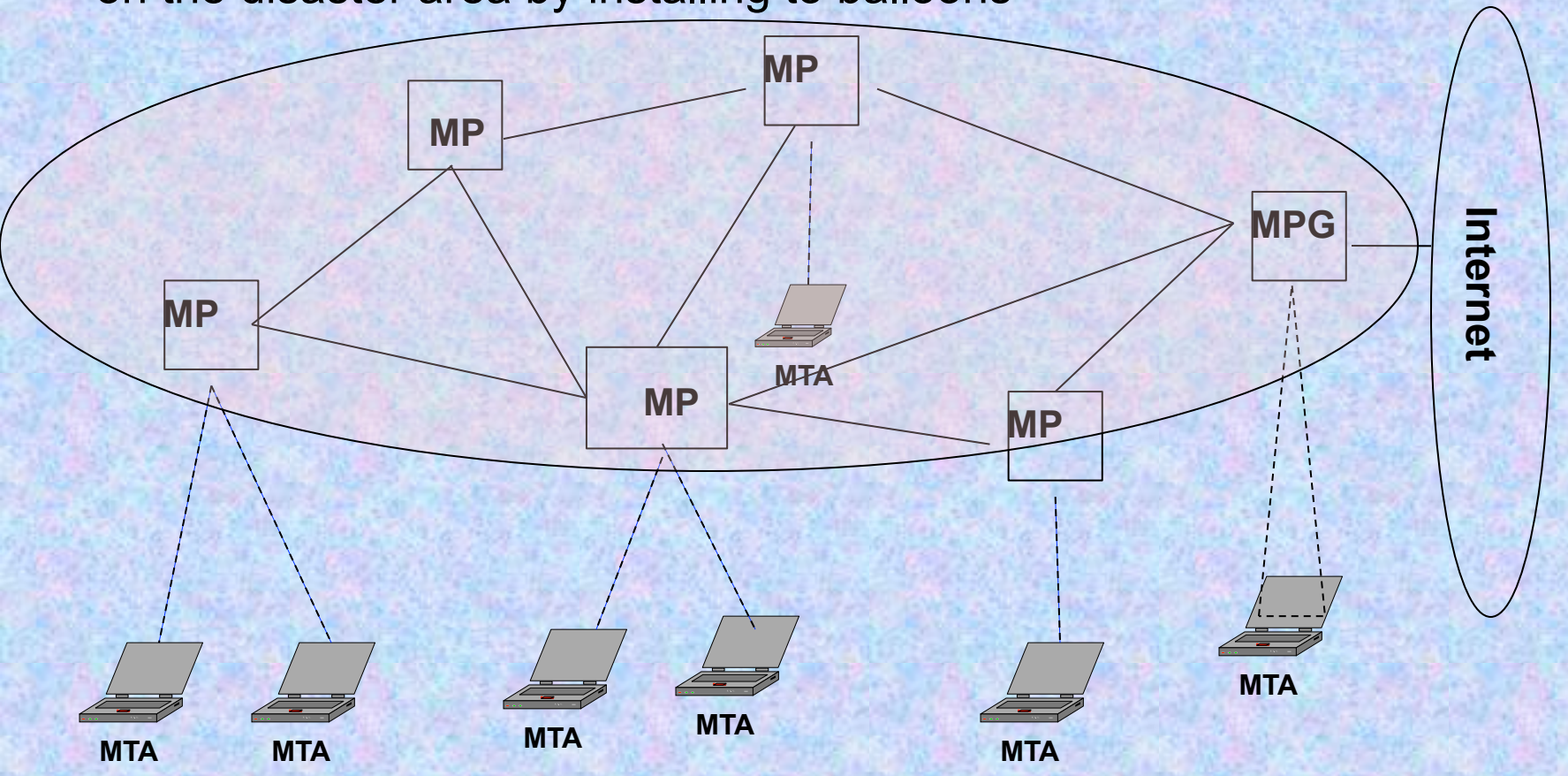
Disadvantages

- Limited Communication range : Max 2~5 Km (for IEEE802.11b/g)
- Signal distortion by influence buildings on the ground

Therefore, by installing WLANs to balloons and by multi-hopping those in the sky over ground, more useful disaster information can be realized

Introduction of Ballooned Wireless Mesh Network

- Both backbone and access networks can be established by multiple mesh pints
- In horizontal, backbone network can organize an adhoc network, while in vertical, each mesh point can support multiple MTA access
- Thus, mesh network can deploy as a temporal emergency network covered on the disaster area by installing to balloons



Purpose

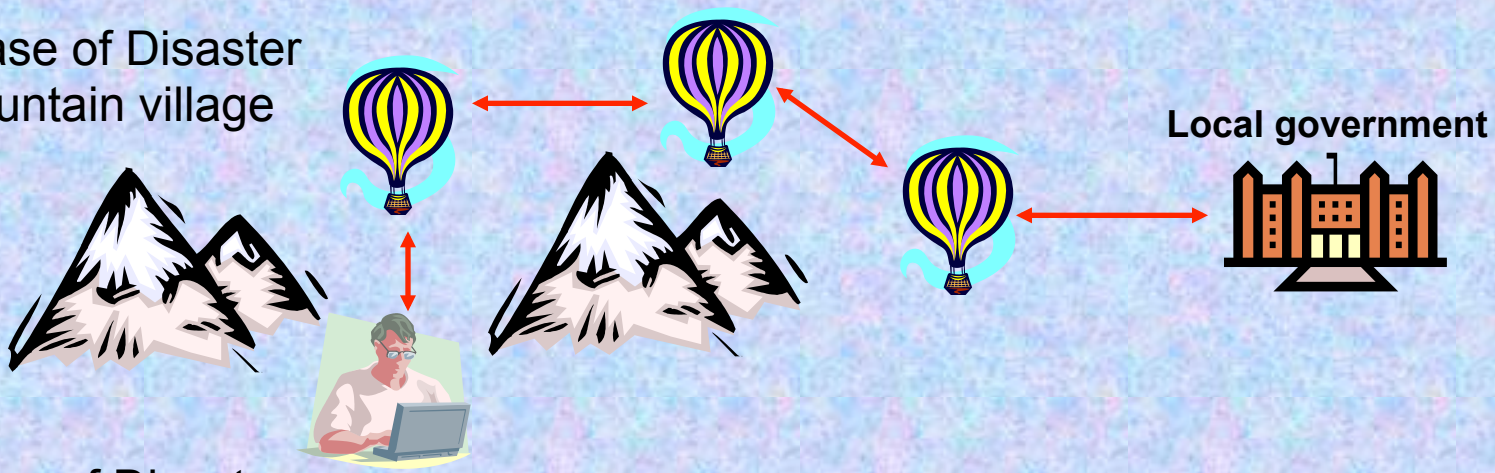
To construct wide-area wireless mesh network by combining balloons and Wireless mesh network(BWMN) for disaster information network :

- To prototype BWMN system using conventional commercially available WLANs such as IEEE802.11b/g/j
- To evaluate performance the BWMN prototype
- To offer various information service applications useful when disaster happened
  - WIde-area Disaster Information sharing System
  - Wireless IP telephone network
  - Ballooned wireless video surveillance network

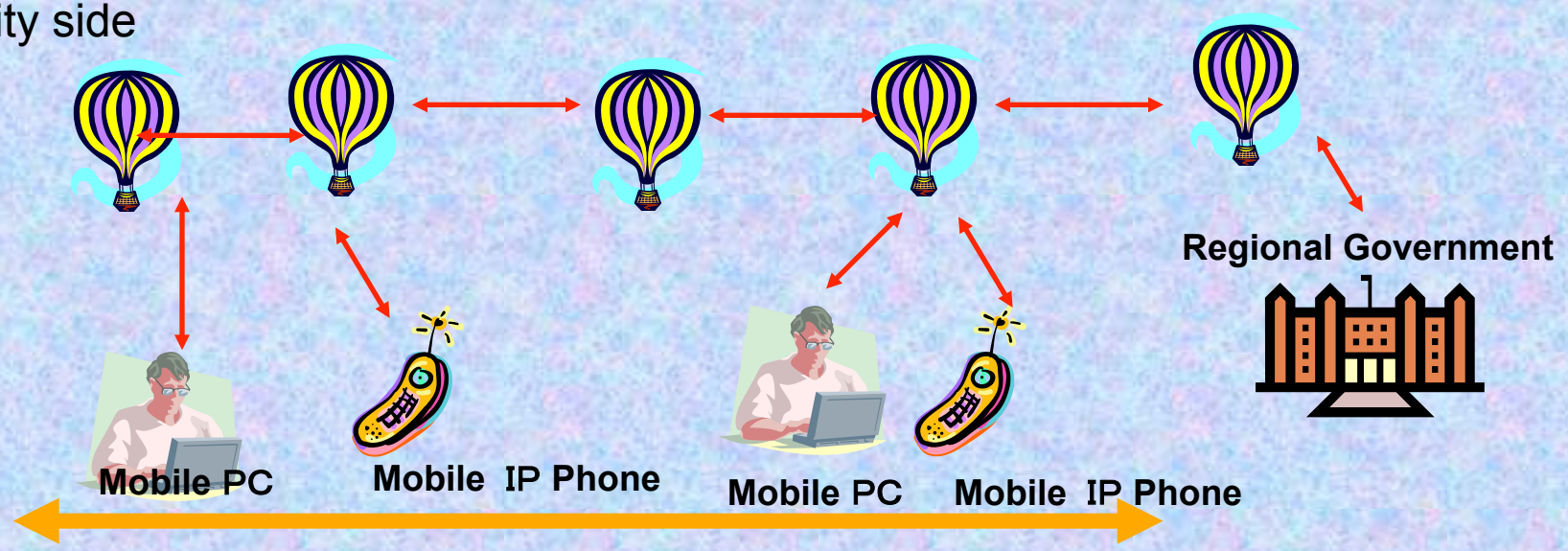
BWMS as Disaster Information Network

Combination of Balloon and BWMS and multi-hopping

1) In case of Disaster at mountain village



2) In case of Disaster at city side

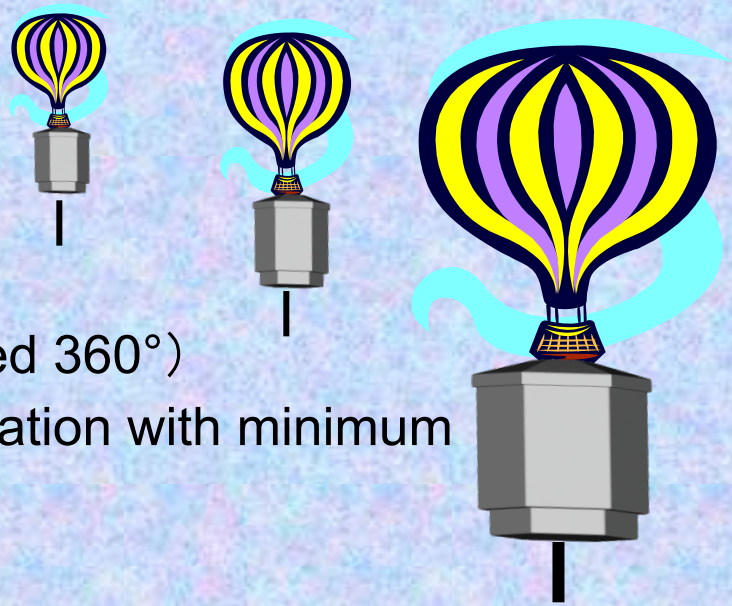


Prototyping Two BWMS

- Although IEEE802.11s is standardized for mesh network, there is no commercial product
- We prototyped two BWMSs using current available standard LANs with different antennas

  - Type 1: combination of IEEE802.11j + IEEE802.11b/g
  - Type 2: combination of IEEE802.11b + g

Characteristics of Type 1 BWMN



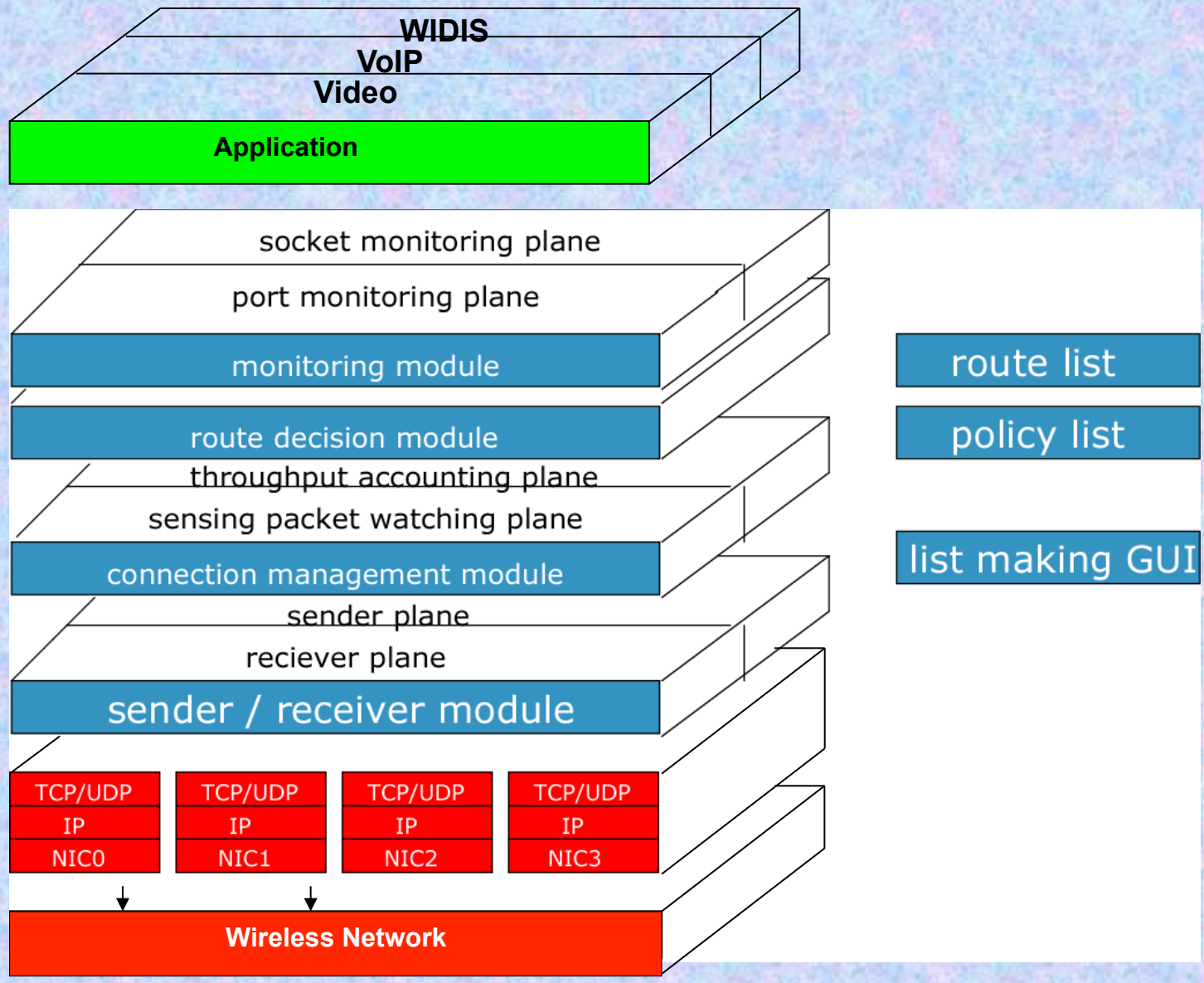
1）Horizontal (Back bone network)

- Standards：IEEE802.11j
- Power：250mW
- Data Transmission：54Mbps
- Antenna：6 directions plane antenna (covered 360°)
- Adhoc function：Automatic Network configuration with minimum spanning tree according signal power

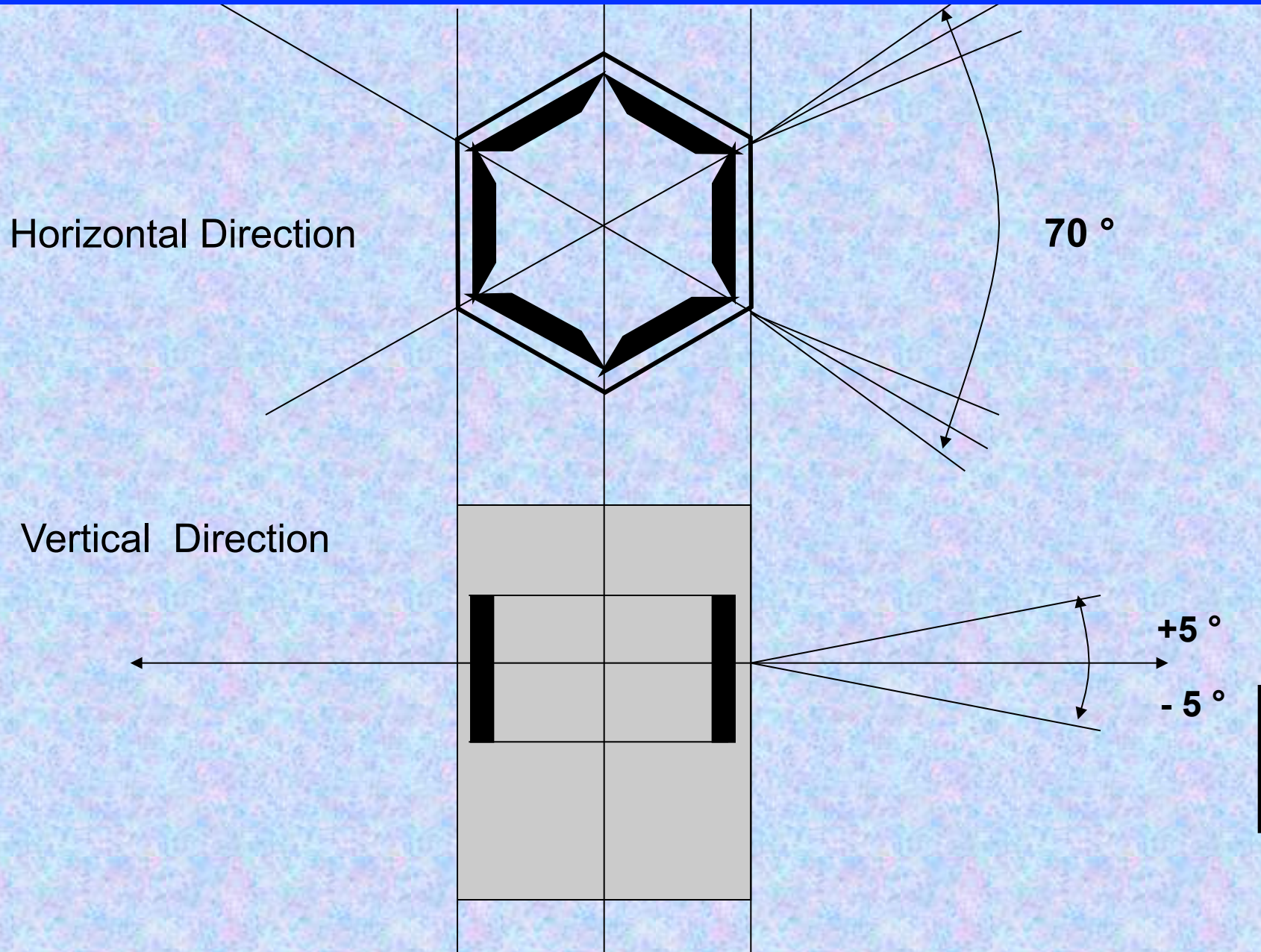
2）Vertical (Access network)

- Standards：IEEE802.11b/g
- Power: 10mW
- Data Transmission: Max 54Mbps
- Antenna：co-linear antenna

System Architecture



Antenna Direction of Type 1



Characteristics of Type 2 BWMN

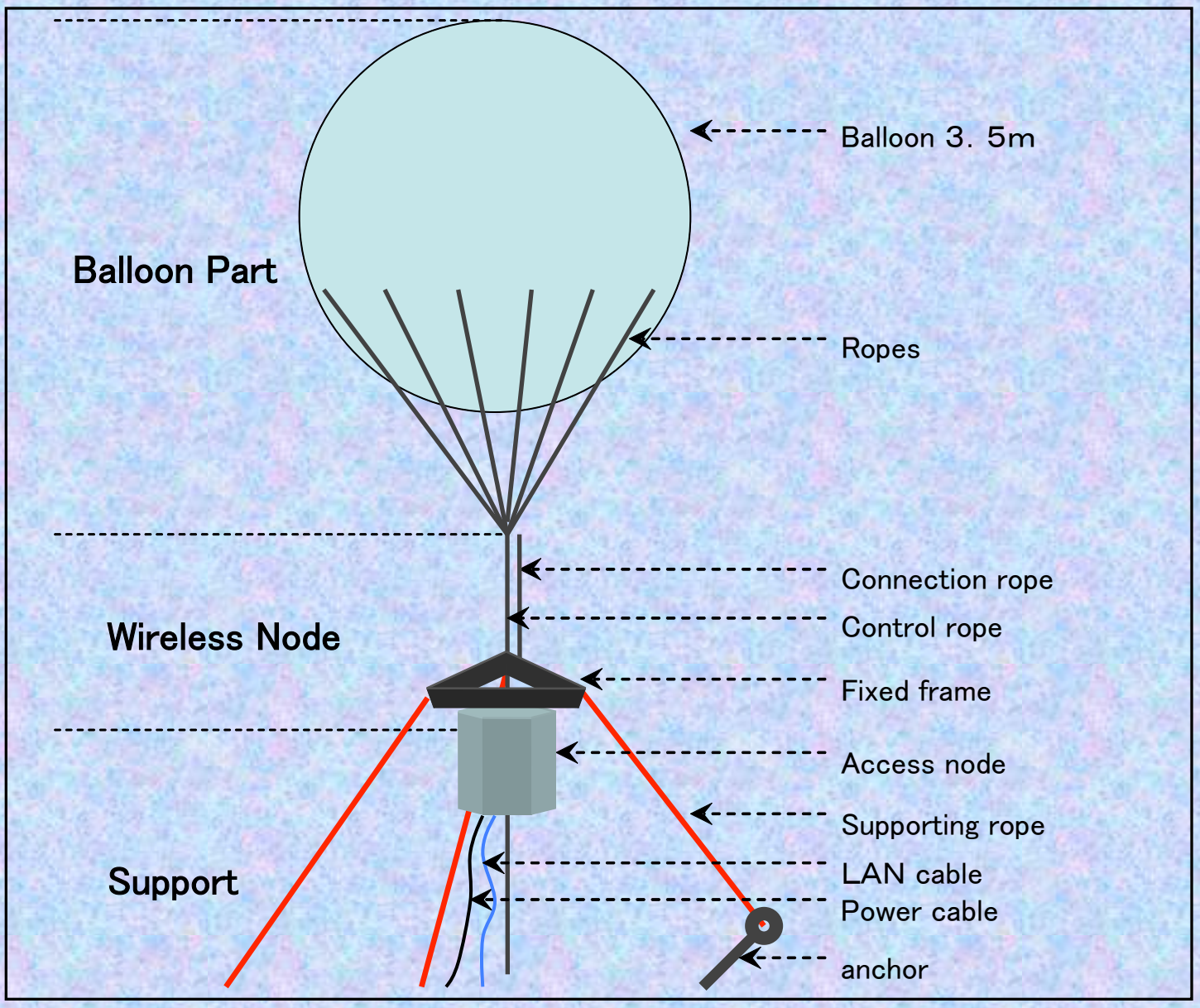
1）Horizontal (Back bone network)

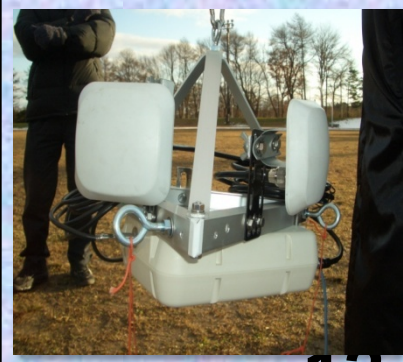
- Standards：IEEE802.11g
- Power：10mW
- Data Transmission：54Mbps
- Antenna：2 directions patch antennas (covered 180°）
- Adhoc function：Automatic Network configuration with minimum　spanning tree according signal power

2）Vertical (Access network)

- Standards：IEEE802.11b/g
- Power: 10mW
- Data Transmission: Max 54Mbps
- Antenna：plane antenna

Ballooned Wireless Mesh Network Node

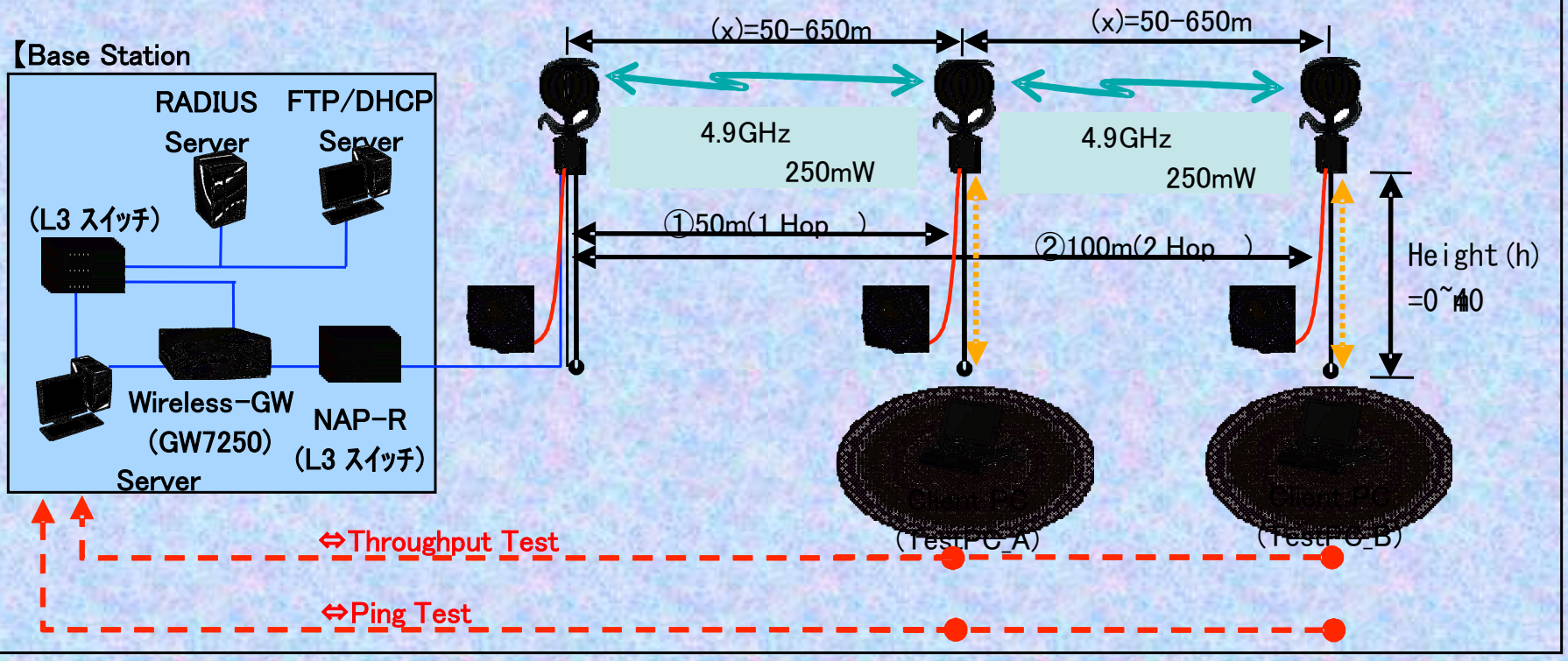




Performance Evaluation of Type 1 BWMN

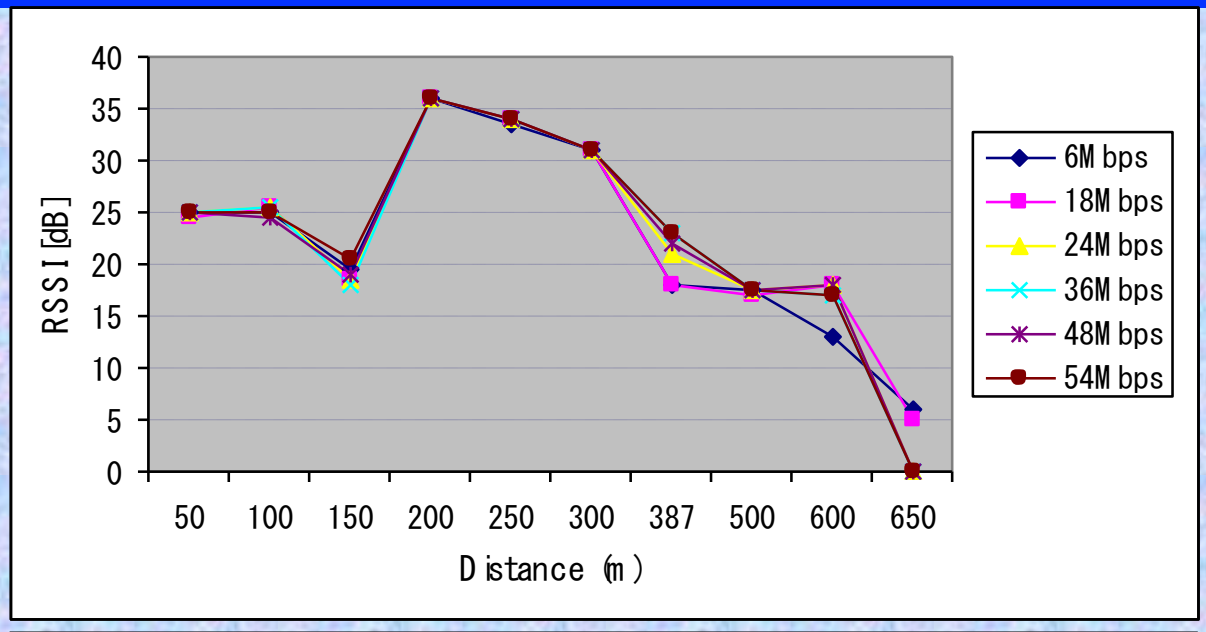
- Evaluation of transmission propagation characteristics
- Horizontal Direction (IEEE 802.11j, 4.9GHz) and Vertical Direction (IEEE 802.11b,g, 2.4GHz) with various parameters:
  - distance,
  - height difference,
  - signal power,
  - the No. of hoppings
  - antenna direction
  - wind influence

Transmission Characteristics: Type 1 BWMN
Horizontal (4.9GHz), Vertical(2.4GHz)



Result of Propagation Characteristics: Type 1 BWMN Horizontal Direction vs. RSSI and Packet Arrival Rate

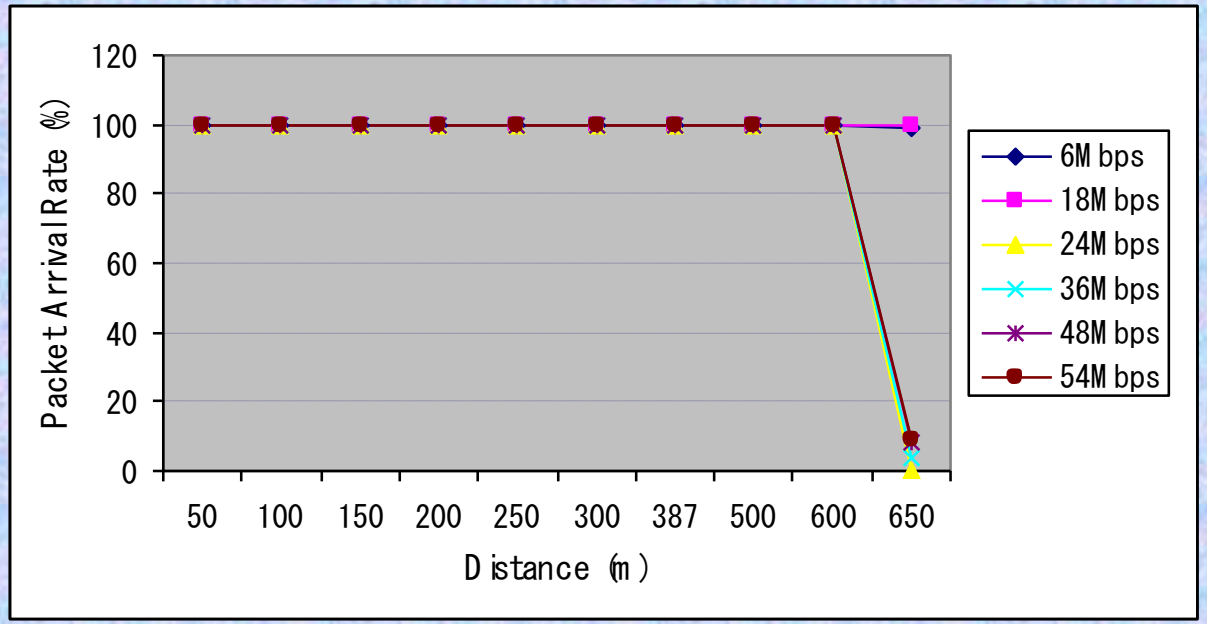
Distance vs. Ave. RSSI [dB]
Sending Signal Power:
250mw



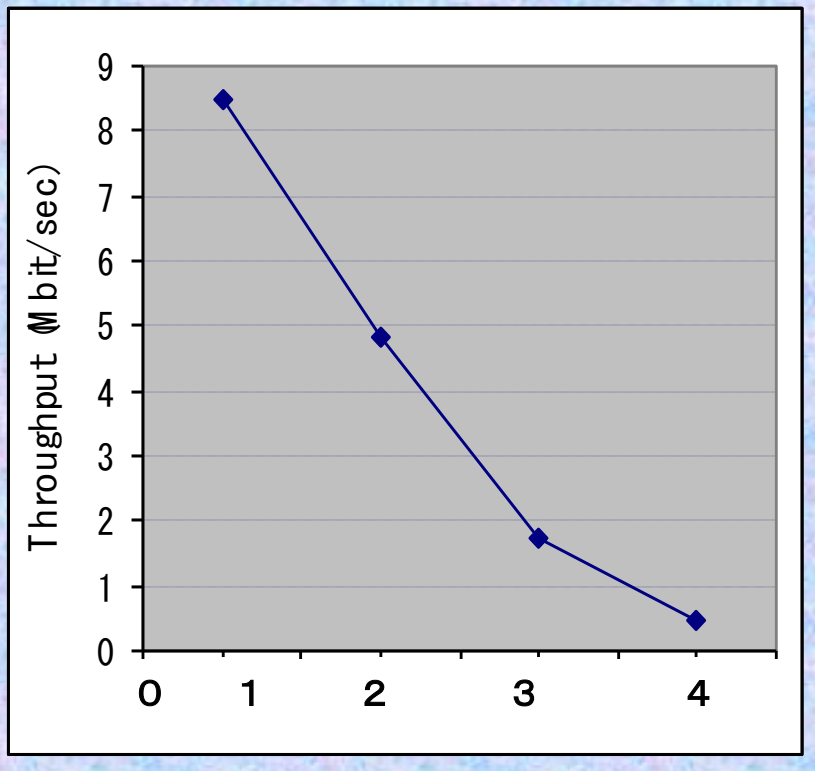
Distance vs.
Packet Arrival Rate [%]

Sending Signal Power:
250mw

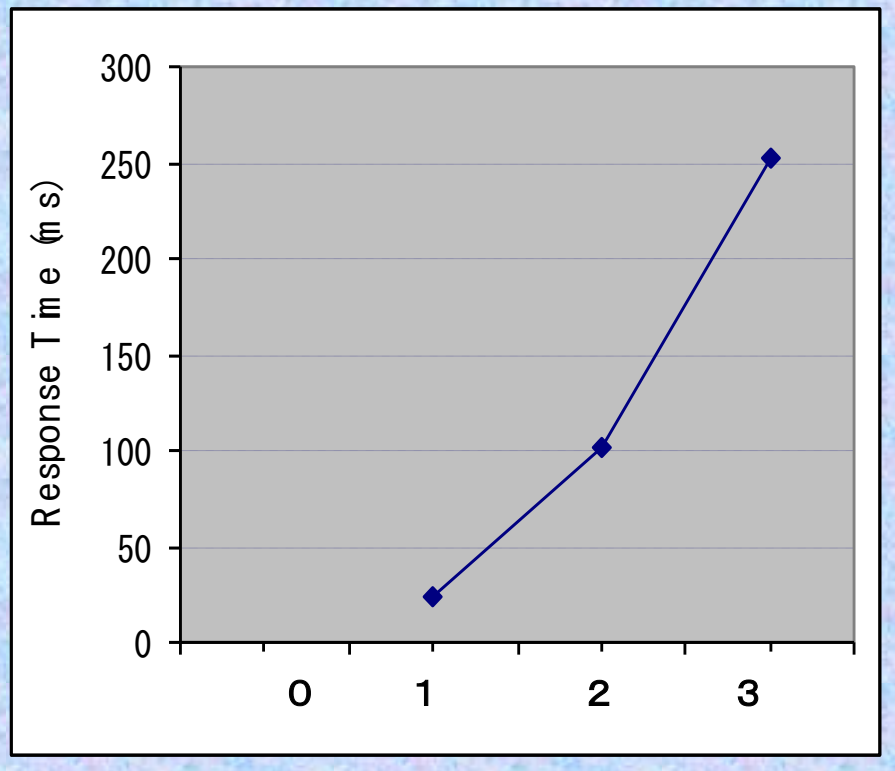
RSSI: Received Signal Strength Indicator)



Result of Influence of the Number of Hopping : Type 1 BWMN

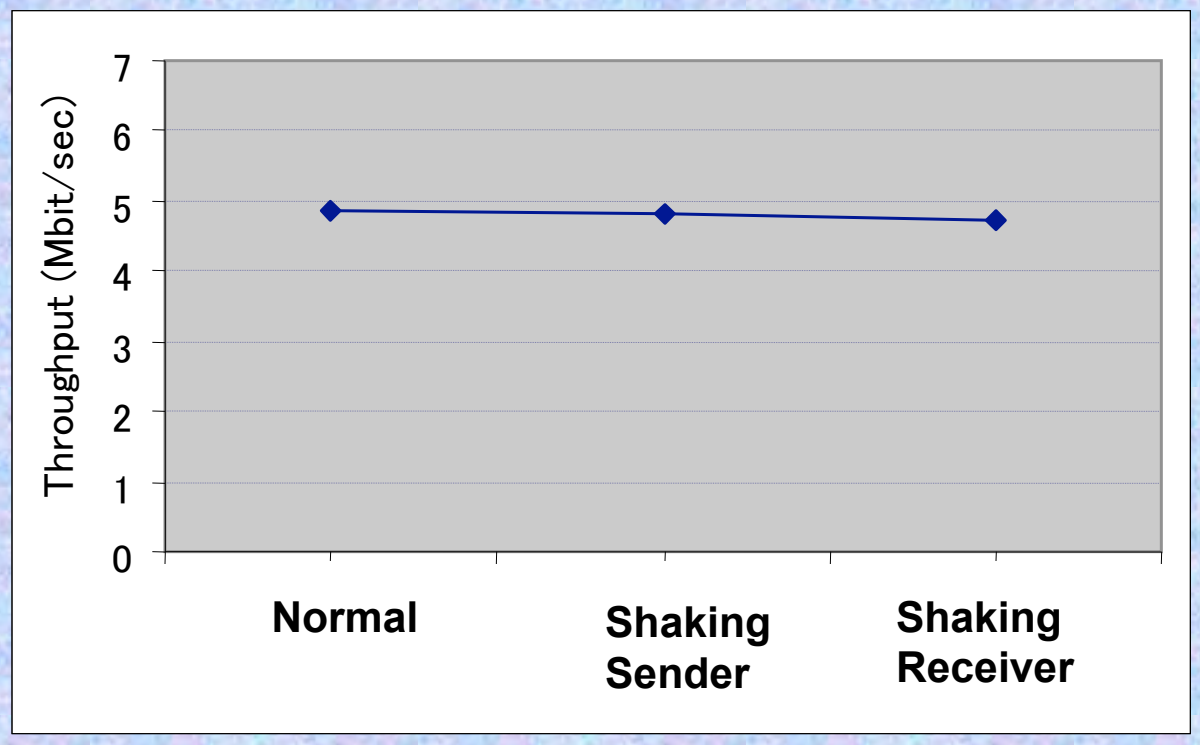


The No. of Hopping
vs.
Throughput (Mbps)



The No. of Hopping
vs.
Response Time (ms)

Result of Influence of Shaking Access Point: Type 1 BWMS



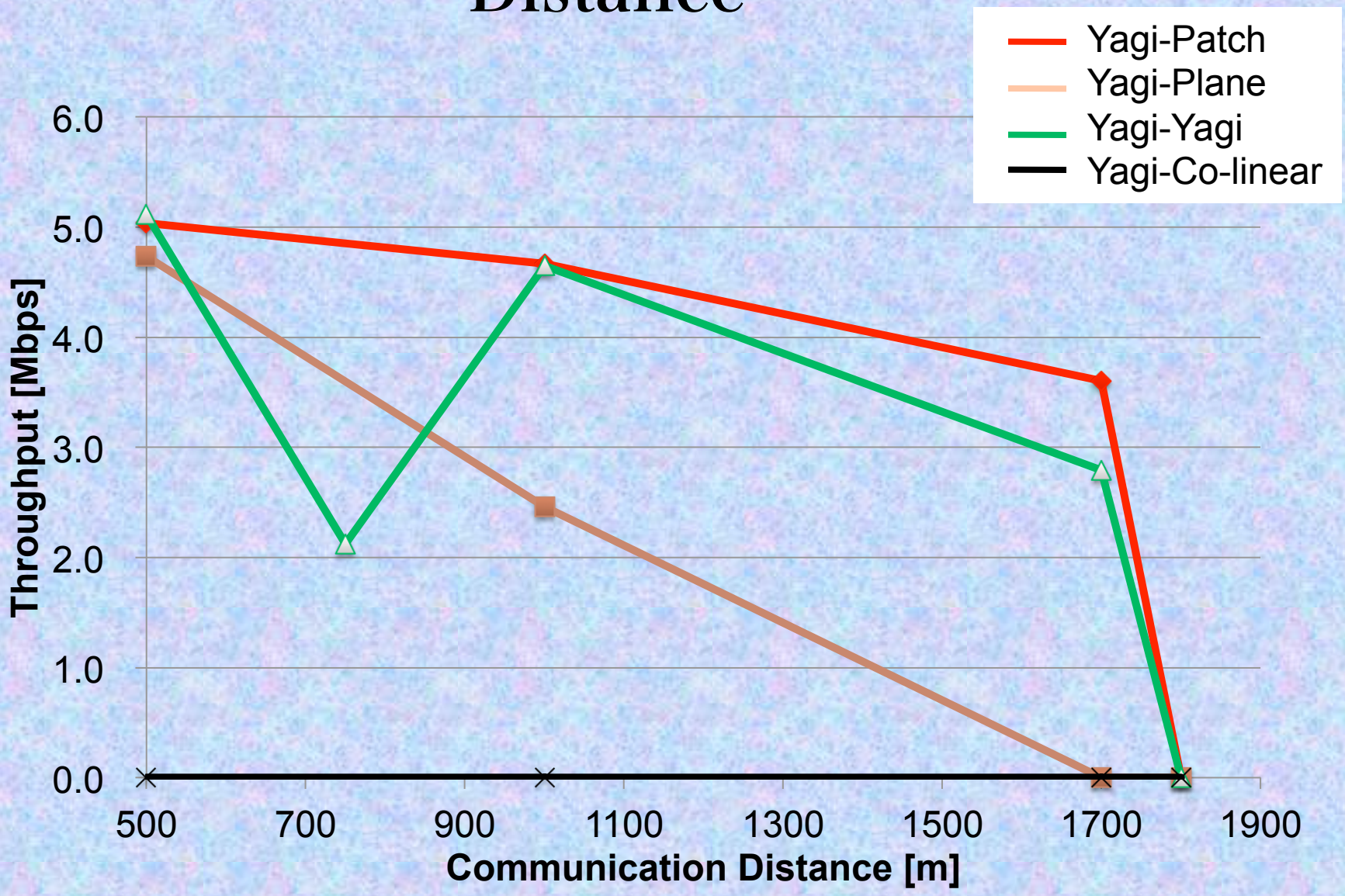
Throughput (Mbps) when Shaking

- Shaking strongly sender and receiver AP by hand equivalent to 10 (m/s)

Performance Evaluation of Type 2 BWMN

- Evaluation of transmission characteristics
- Horizontal Direction (IEEE 802.11b,g, 2.4GHz) and Vertical Direction (IEEE 802.11b,g, 2.4GHz) with various parameters:
  - communication distance,
  - height difference,
  - antenna direction

Result of Propagation Characteristics: Type 2 BWMN Throughput vs. Horizontal Distance for different antennas



Result of Characteristics: Type 2 BWMN
Throughput & Packet Loss Rate vs. Horizontal Distance

45m

Distance

Throughput

Packet Loss Rate

Throughput [Mbps]

5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00

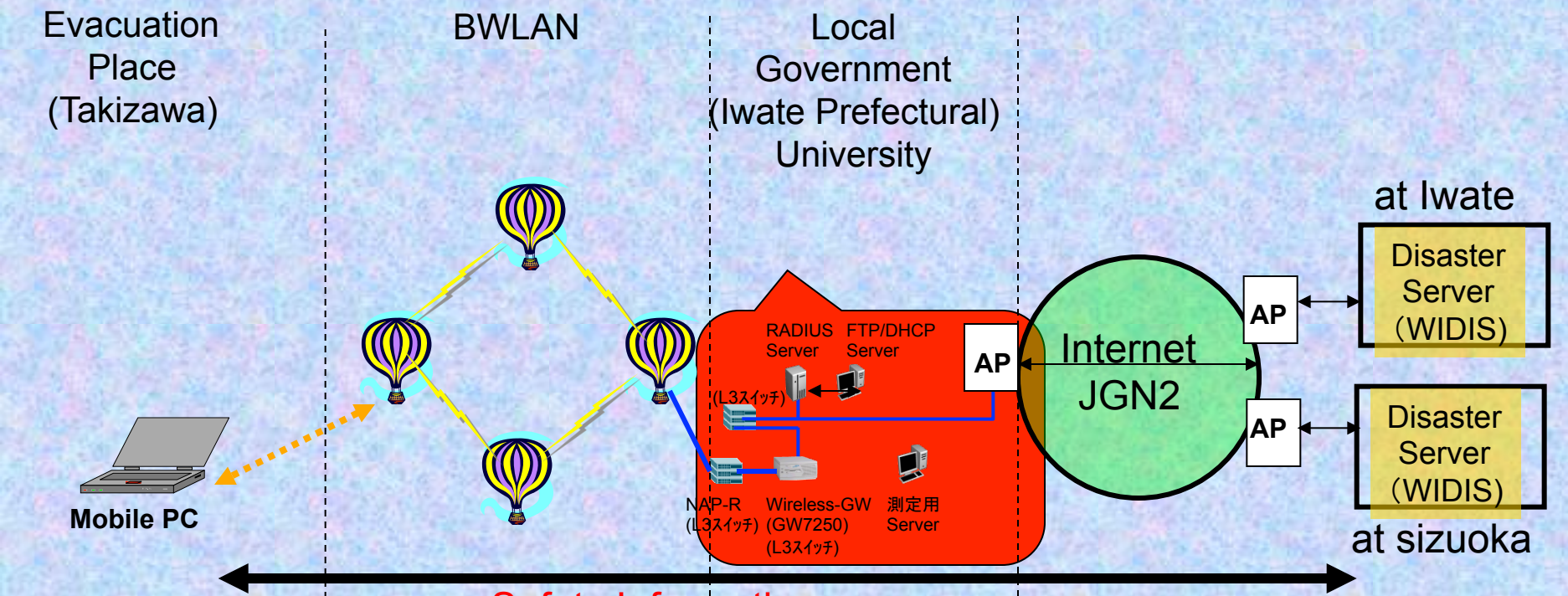
Packet Loss Rate [%]

100
90
80
70
60
50
40
30
20
10
0

0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150

Distance between balloon and relay station [m]

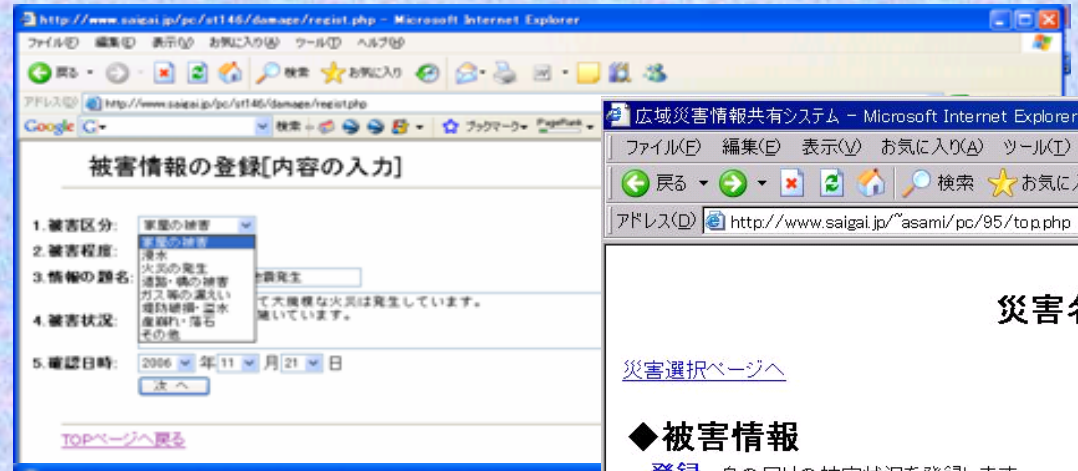
Performance Evaluation of WIDIS

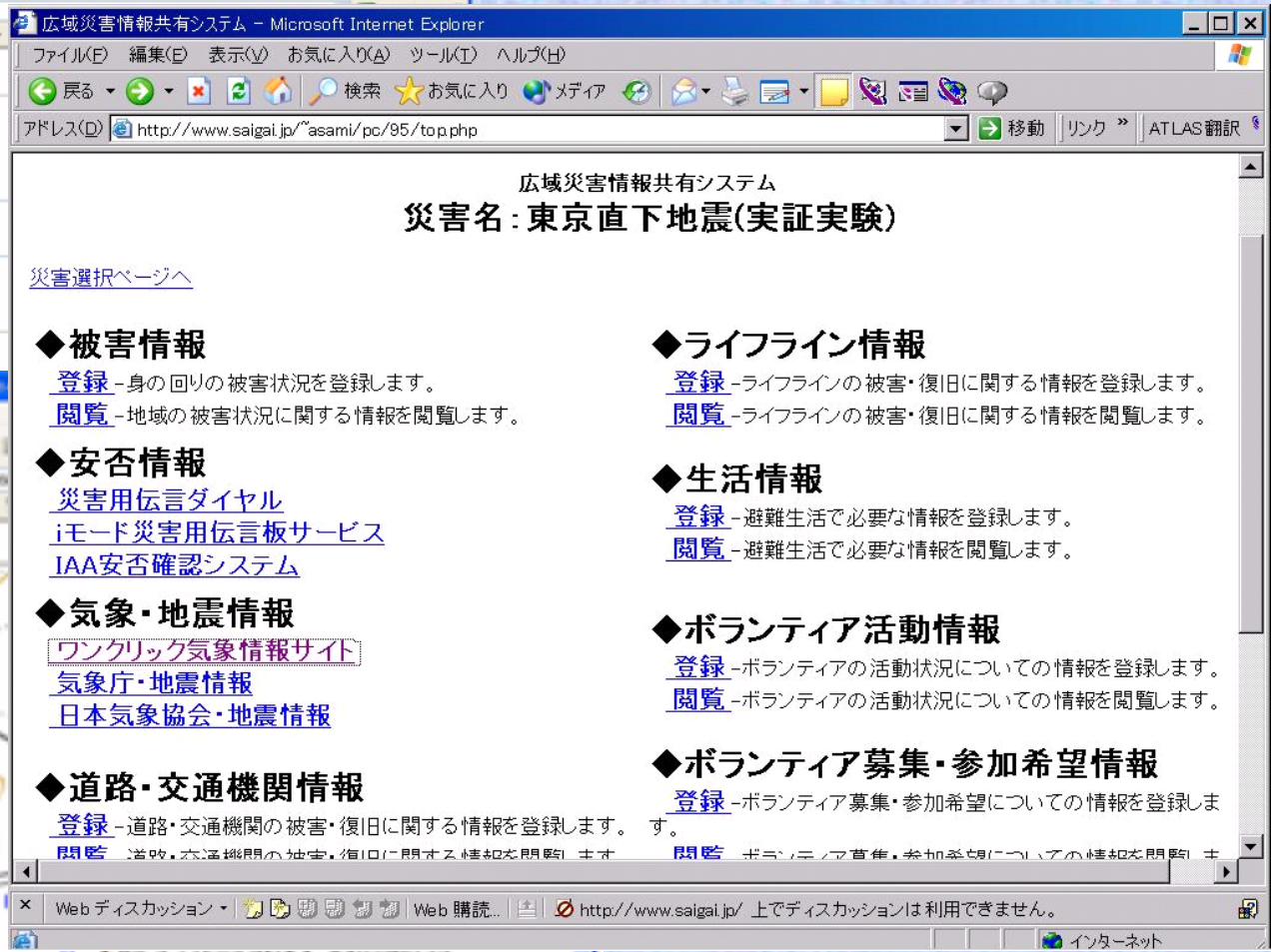


Safety Information
Disaster Information
Lifeline information

Result:
50 users could access to WIDIS Server without performance degradation

Wide Area Disaster Information Sharing System

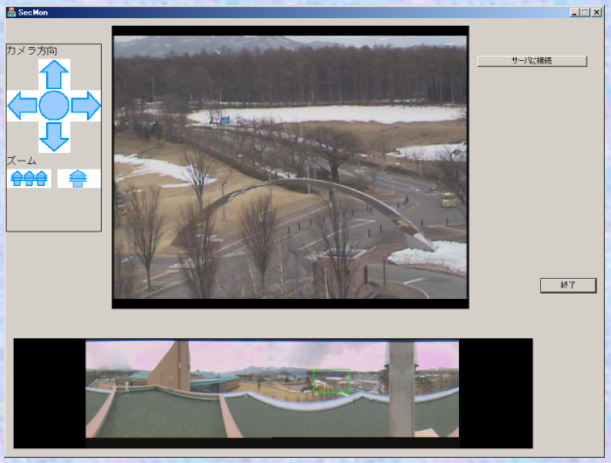




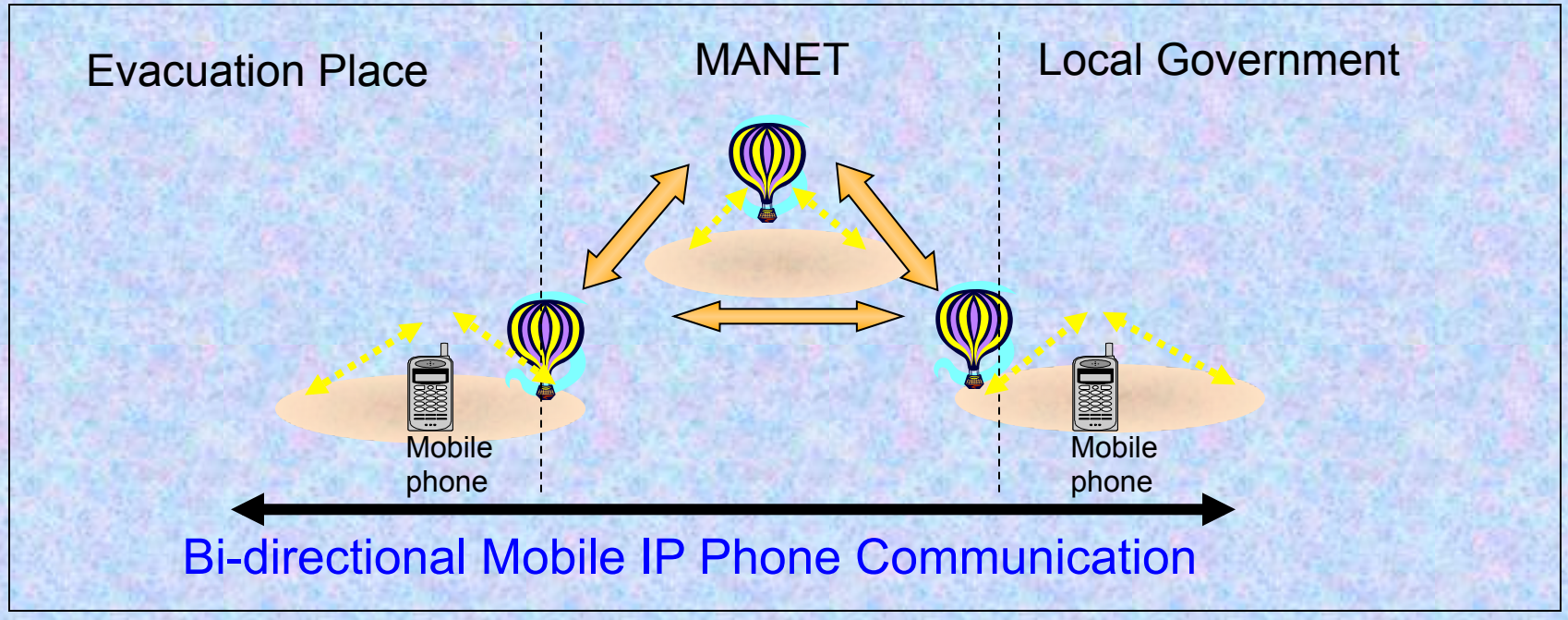
Performance Evaluation of Three Different Applications on BWLAN

We developed three difference disaster applications

- WIde-area Disaster Information sharing System based on Web GIS (WIDIS)
- Wireless IP telephone network
- Ballooned wireless omni-directiona video surveillance System

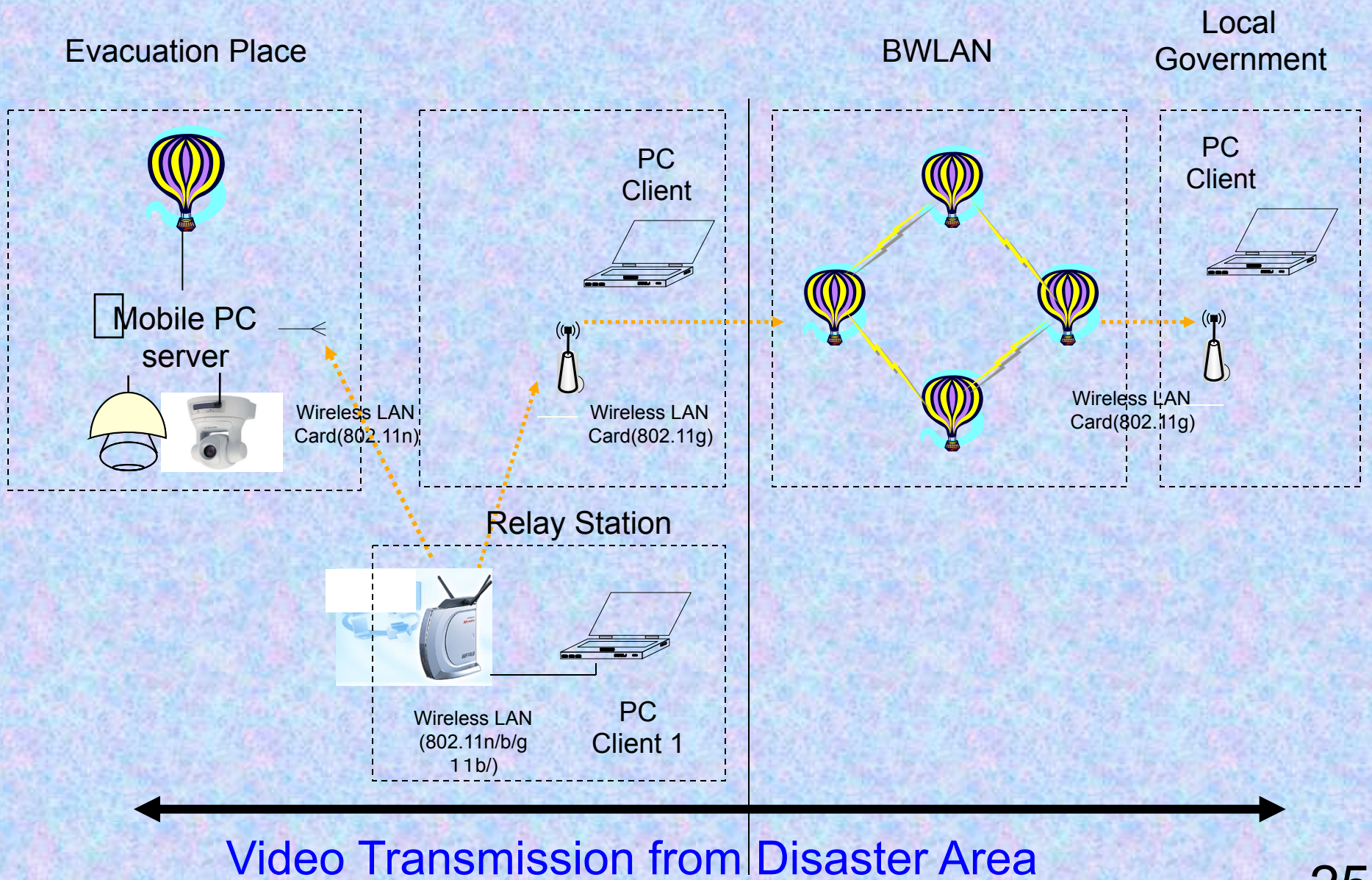


Performance Evaluation of Mobile IP Phone by BWLAN



- Good voice quality
- within 240 msec time delay

Performance Evaluation of Realtime Video Streaming by BWLAN



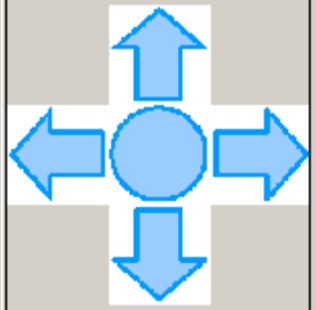
Realtime Video Streaming System over BWMN


PLEASE RECYCLE
STORE AT 14°C
Panasonic
Let's note

Camera Control by Remote Operation

SecMon

カメラ方向



ズーム

サーバに接続

終了

Result of Video Transfer Function

Video image	Omni-Directional	PTZ camera
Size	800x250	320x240
Format	WMV	WMV
Req. BW	2 Mbps	1 Mbps
Frame Rate	10~15	10~15

Concluding Remarks and Future Works

Conclusions

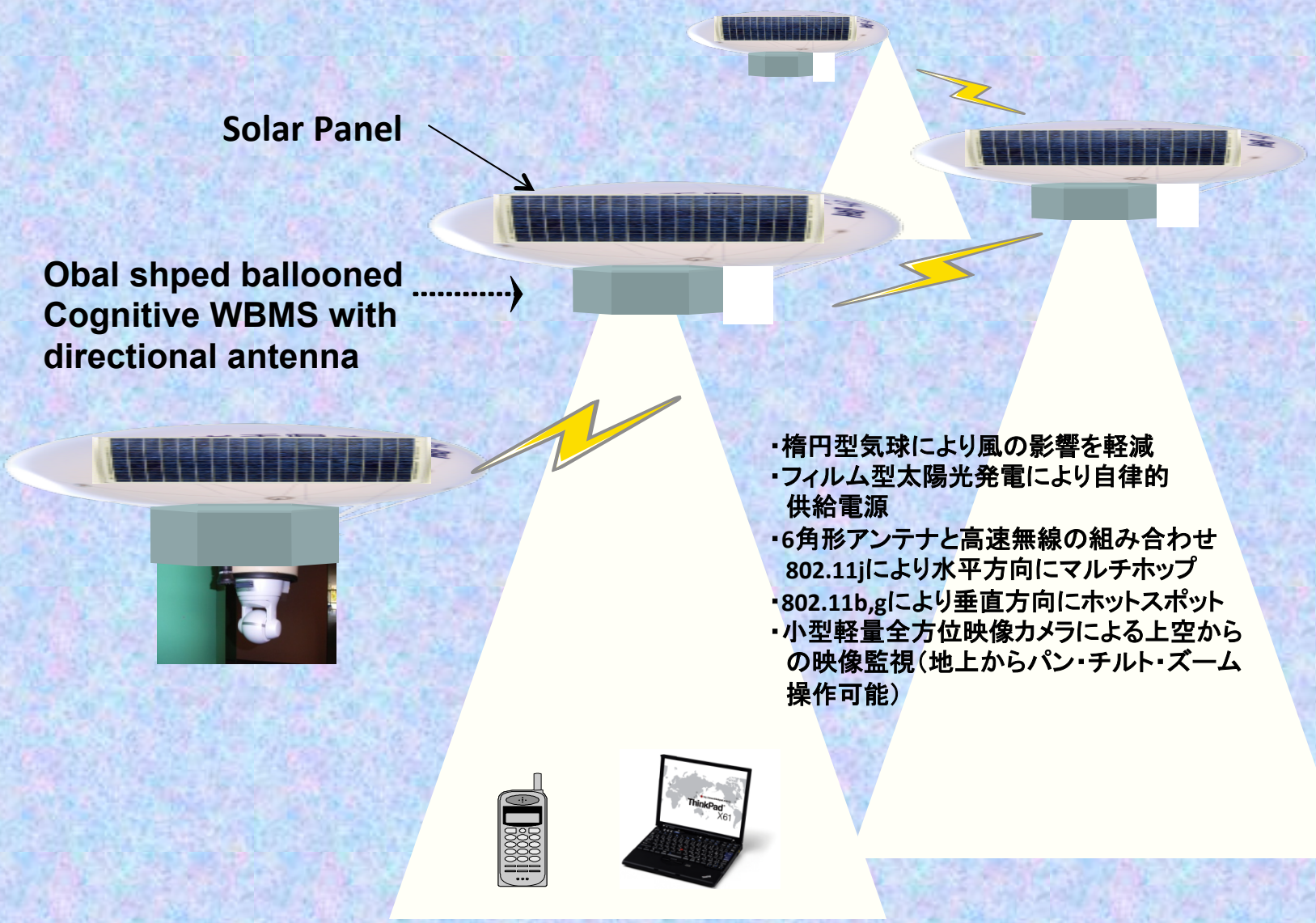
In order to realize robust wide area disaster information network,

- introduced ballooned wireless mesh network
- prototyped two types of BWMN using conventional standard wireless LAN such as IEEE802.11b,g,j
- Evaluated performance of throughput, packet loss rate for both BWMSs
- Also evaluated the performance of disaster applications, including Web GIS, Wireless IP Phone and Video.
- Through the performance, verified the usefulness

Future Works

- Stabilization of Balloon in the sky against strong wind
- Simple operation miniaturization of Balloon with small number of person
- Introduction of autonomous disaster information network

Autonomous Disaster Information Network

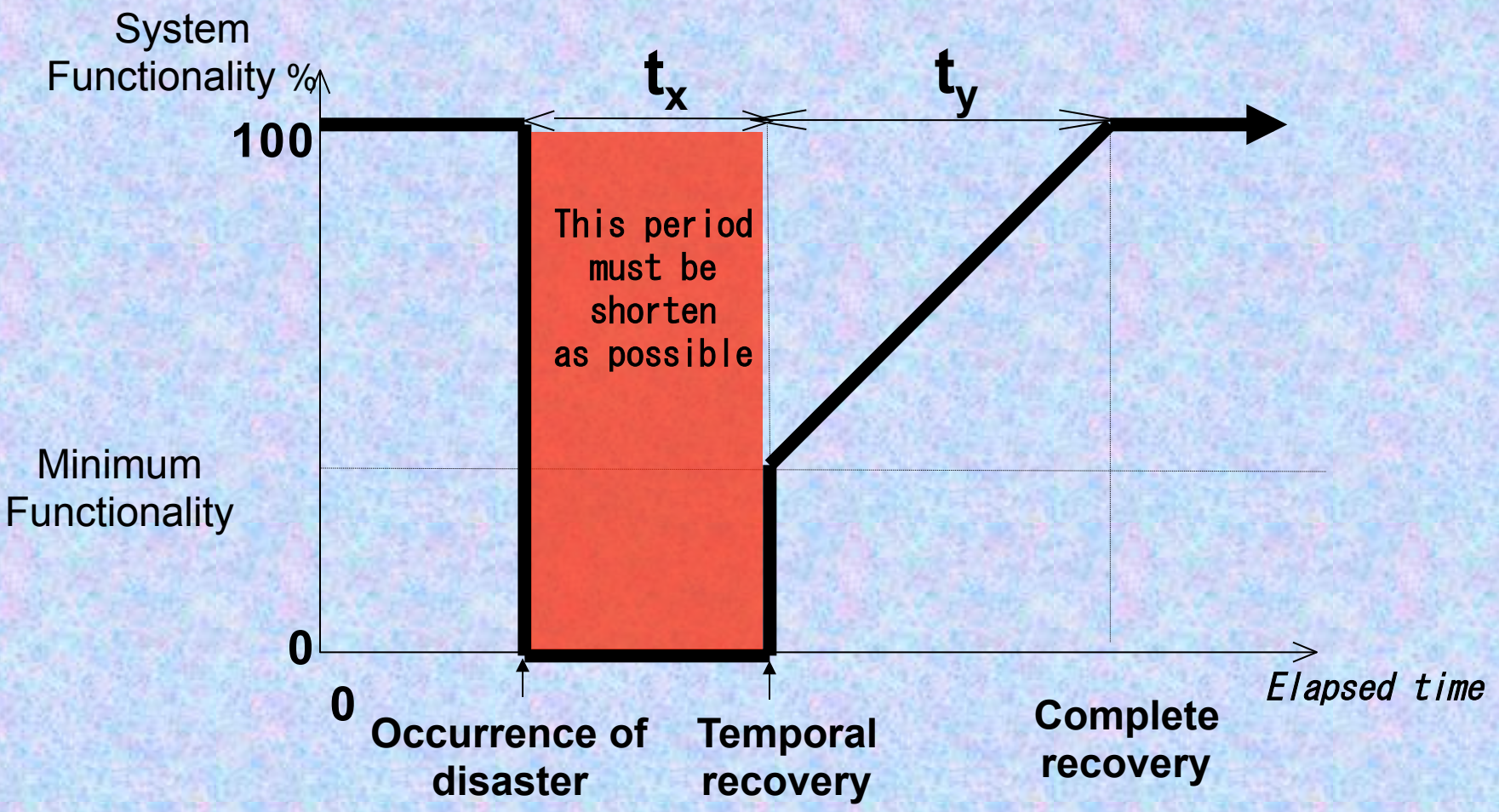


・楕円型気球により風の影響を軽減
・フィルム型太陽光発電により自律的供給電源
・6角形アンテナと高速無線の組み合わせ802.11jにより水平方向にマルチホップ
・802.11b,gにより垂直方向にホットスポット
・小型軽量全方位映像カメラによる上空からの映像監視（地上からパン・チルト・ズーム操作可能）

Thank you for your attention

Quick Recovery Requirement from Failure

System functionality just after disaster is critical



Long Distance Wireless Network

	WHAN IEEE802.11b,g	HWAN IEEE802.11n	WiMAX IEEE802.16e	W Access IEEE802.11j	Subscribed Wireless	Personal Wireless	3G Cellular Phone
Freq.	2.4GHz	2.4GHz	~5GHz	5 GHz	22~38GHz	1.2GHz	800 MHz
MAX. Speed	11, 54Mbps	300Mbps~	75Mbps	54Mbps	165Mbps	128Kbps	1.2Mbps
Sig. Power	10mW	10mW	-	250mW	-	10 W	250mW
Max Distance	~5Km	~5Km	10Km	30Km	4Km	20Km	10Km
License	Not Required	Not Required	Required	Registered	Required	Required	Not required